Lasers in Surgery and Medicine 21:248–254 (1997)

Comparison of a High Power Diode Laser With the Nd:YAG Laser Using In Situ Wound Strength Analysis of Healing Cutaneous Incisions

Donna-Lee Taylor, DVM,[1]* Steven A. Schafer, PhD,[3] Robert Nordquist, PhD,[4] Mark E. Payton, PhD,[2] D. Thomas Dickey, DVM,[1] and Kenneth E. Bartels, DVM, MS[1]

[1]Department of Small Animal Medicine and Surgery, Boren Veterinary Medical Teaching Hospital, Stillwater, OK 74078
[2]Department of Statistics, Oklahoma State University, Stillwater, Oklahoma 74078
[3]Department of Physics, Oklahoma State University, Stillwater, Oklahoma 74078
[4]Wound Healing of Oklahoma, Oklahoma City, Oklahoma 73177

Background and Objective: **The laser-tissue interaction of a high power semiconductor diode laser was compared to the continuous wave neodymium yttrium aluminum garnet (Nd:YAG) laser by evaluating primary wound healing of cutaneous incisions in rats.**
Study Design/Materials and Methods: **Full thickness incisions were made in rat skin using a diode laser (805 nm, 10 W, contact mode), an Nd:YAG laser (1,064 nm, 10 W, contact mode), and a stainless steel scalpel blade (control). In situ wound breaking strength measurements were obtained at 7, 14, and 21 days using a specially designed tensiometer. Cross sectional area of non-disrupted wounds was calculated in two groups prior to testing to allow for calculation of tensile strength. Blinded histopathologic analysis was also performed.**
Results: **Analysis of variance ($P \leq 0.05$) was used to determine differences in breaking strengths and tensile strengths due to incision method. There was no significant difference in the breaking strengths (group 1) or tensile strengths (groups 2 and 3) of the diode and Nd:YAG laser incisions. As predicted, breaking strengths and tensile strengths of scalpel blade incisions were significantly greater than those of incisions made with laser energy. Histopathologic evaluation revealed that through day 14, the degree of inflammation and collagen production was similar for diode and Nd:YAG laser incisions. Laser incisions had greater inflammation and a lag in fibroblast invasion and collagen production compared with scalpel incisions. By day 21, all incisions were similar in fibroblast population and collagen production, but laser incisions had slightly more inflammation than scalpel incisions.**
Conclusion: **In the primary wound healing model described, the tissue effect, cellular response, and development of wound**

*Correspondence to: Donna-Lee Taylor, D.V.M., Northwest Veterinary Specialists, 21920 S.E. Stark St., Gresham, OR 97030.

Accepted 2 January 1997

strength were essentially the same for the high power diode laser at 10 W and the Nd:YAG laser at 10 W. Lasers Surg. Med. 21:248–254, 1997. © 1997 Wiley-Liss, Inc.

Key words: breaking strength; tensile strength; tensiometer; laser surgery

INTRODUCTION

The continuous wave Nd:YAG laser (1,064 nm) has been used clinically for photothermal tissue ablation in conditions of the gastrointestinal, respiratory, urogenital, and nervous systems. It is the most commonly used laser for vaporization of gastrointestinal tumors, most notably, palliation of esophageal neoplasia [1,2]. Vascular lesions such as peptic ulcers, gastrointestinal angiodysplasia, antral vascular disease, and radiation induced lesions have been successfully treated with Nd:YAG laser energy delivered through a quartz fiber in non-contact mode [3–5]. In otolaryngology, the Nd:YAG is used for palliation of obstructive tracheobronchial lesions, photocoagulation of vascular lesions of the head and neck, and photocoagulation of lymphatic malformations [6–13]. The use of the Nd:YAG laser for prostatectomy is associated with reduced risks and cost compared to the more traditional transurethral resection of prostatic tissue using an electrocautery loop or TURP technique [14]. Photoablation of ureteral and renal pelvis carcinomas using the Nd:YAG has also been reported [15,16]. In the field of neurosurgery, the Nd:YAG has been used in operating intracranial tumors and cranial and spinal arteriovenous malformations [17–21]. Although it is an effective instrument for hemostatic tissue ablation, the Nd:YAG tends to be cumbersome in design and operation. The semiconductor diode laser provides for a high operating efficiency with its standard 110–240 V AC power requirement and low waste heat production. The lower power diode laser (<2 W) has been utilized in the medical field during the past decade, primarily for ophthalmic procedures. The high power diode laser has only recently become commercially available and was F.D.A. approved in 1993. Since few published studies describe the laser-tissue interaction of this device, its potential medical application is still under investigation. In one clinical study where the Diomed 25 W laser was effectively used for incising urethral strictures and excising small bladder tumors without anesthesia, it was proposed that the semiconductor diode laser would replace the Nd:YAG for these procedures [22]. The authors of a non-clinical study also suggested that the high powered diode laser may be an efficient and compact alternative to the Nd:YAG laser [23]. The purpose of this study was to compare the tissue effects of a high power diode laser and the continuous wave Nd:YAG laser using cutaneous wound healing in the rat as a model. Primary wound healing of cutaneous incisions was evaluated using in situ tensile strength tests and blinded histologic analysis.

Tensile strength is the maximum stress or *force per unit area* existing in a material prior to rupture. Breaking strength is the force responsible for material failure without regard to its dimensions. When critically assessing the strength of nonidentical materials, tensile strength provides a more valid comparison.

MATERIALS AND METHODS

Medical Lasers

The high power diode laser (Diomed 25, Surgimedics ESP, Inc; The Woodlands, TX) used in this study is a continuous wave laser with an emission wavelength of 805 nm ± 25 nm, and has a power range of 0.5–25 W. The aiming beam is a visible light diode laser having a wavelength of 650 nm. This portable unit weighs 12 kg and has dimensions of 38.0 × 40.5 × 15.0 cm. The continuous wave Nd:YAG laser (Medilas 2 YAG-Nd:YAG, MBB-ATT Angewandte, Technologie, GmbH Munich, Germany) used has a power range of 5 to 110 W, and a wavelength of 1,064 nm. The aiming beam for the Nd:YAG is a 2 mW helium-neon laser (633 nm wavelength). Laser energy from both units was applied in contact mode using a flexible quartz fiber (≠9S-5244 300 μm tip, Surgimedics ESP, Inc.).

Study Protocol

Thirty-six sexually mature male, viral antibody-free, Sprague-Dawley rats were used in the study. The rats were cared for and the project conducted in a manner consistent with the U.S. National Institute of Health "Guide for the Care and Use of Laboratory Animals" and the Animal Welfare Act.

The rats were anesthetized with halothane

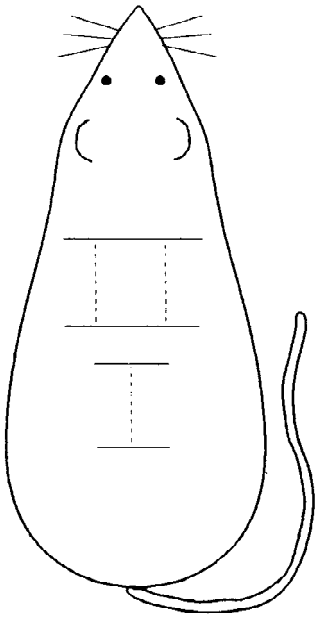

Fig. 1. Broken lines represent original test incisions. Horizontal lines represent incisions made to allow measurement of wound thickness prior to strength testing.

for preoperative preparation and surgery. Standard aseptic technique was used to prepare the dorsal body as the surgical field. All rats received a perioperative subcutaneous injection of butorphanol (0.4 mg/kg) for postoperative analgesia [24].

Three full thickness skin incisions, 2 cm in length, were made on the dorsum of each rat (Fig. 1). Randomly sequenced incisions were made with the diode laser (10 W, continuous), the Nd:YAG laser (10 W, continuous), and a number 15 stainless steel scalpel blade (control). The power output that provided effective cutting with the least gross peripheral carbonization in creating full thickness incisions in rat skin was selected for each laser in a pilot study. Based on these criteria, the power setting selected for both lasers was 10 W. The laser incisions were made in contact mode at an average rate of 0.5 cm per second. The estimated power density of the laser incisions was 1.4×10^4 W/cm^2, where power density = power (10 W)/area of fiber tip (7.07×10^{-3} cm^2). As a consequence of the thickness of rat skin, three complete passes of the quartz fiber were required to create an incision using either of the lasers. The contact time necessary to create an incision produced approximately 1 mm of grossly apparent eschar on the incision margins.

All incisions were closed immediately with three 4-0 stainless steel sutures, and all animals were recovered from anesthesia. The animals were divided into three test groups of 12 rats representing three time intervals of wound healing. Group 1 was evaluated at 7 days, group 2 at 14 days, and group 3 at 21 days after surgery.

At 7, 14, and 21 days after surgery, the animals of groups 1, 2, and 3 were re-anesthetized. Two rats from each group were randomly selected for histopathologic evaluation of the incisions. The skin of the back was harvested en bloc, stapled to cardboard to prevent shrinkage, and preserved with 10% buffered formalin solution. In all remaining animals, breaking strength values of in situ wounds were obtained within 10 minutes of euthanasia. The protocol was changed in groups 2 and 3 to allow for measurement of the non-disrupted wound thickness and determination of wound cross sectional area for calculation of tensile strength. Prior to euthanasia of anesthetized rats in groups 2 and 3, full thickness skin incisions were made perpendicular to either end of the original test incisions using a scalpel blade (Fig. 1). Wound thickness and length were then measured with a 6-inch Vernier orthopedic caliper (≠1103-107, Sontec, Englewood, CO) for calculation of wound cross-sectional area.

Measurement of Wound Strength

Breaking strength measurements of the cutaneous incisions were obtained in situ using a tensiometer specially designed for this project (Fig. 2). The tensiometer was interfaced to an IBM PS/2 computer through a data acquisition card (Keithley Metrabyte DAS-8-PGA). Stress and strain values were recorded by a Microsoft Windows-based program.

The method employed for testing the tensiometer for consistency in rate of distraction involved a comparison of the distraction of two identical springs (27 mm × 6 mm × 0.5 mm stainless steel wire extension springs). Stress-strain curves were generated and compared for each of the springs prior to incisional strength testing.

At the time of incisional strength testing, folds of skin on either side of the incision were secured in the tensiometer clamps and distracted at a constant rate of 0.25 mm/sec.

Tensile strength was calculated using the following equation.

$$TS = \frac{BS}{A(\text{length} \times \text{width})}$$

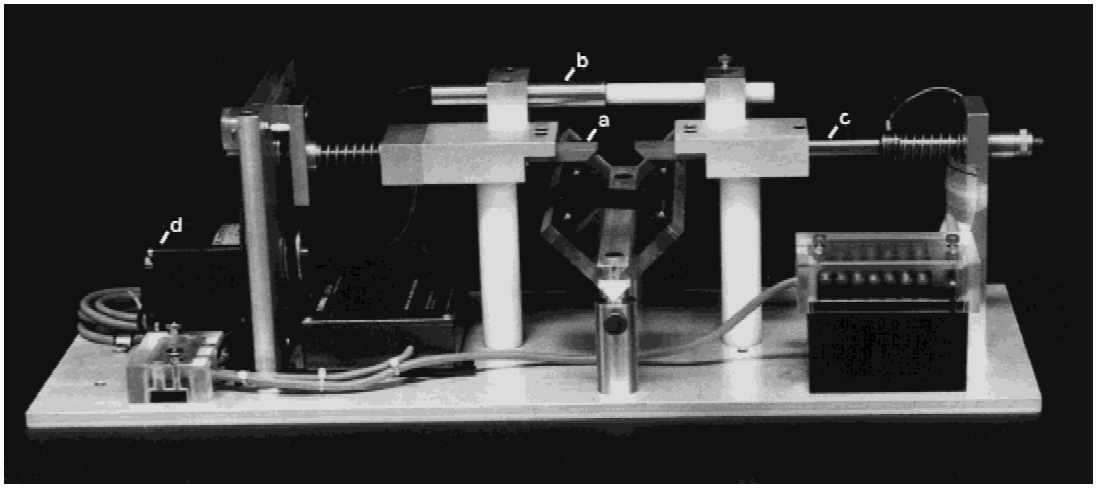

Fig. 2. Tensiometer: **(a)** metal clamps for securing skin folds on either side of the test incision; **(b)** linear variable displacement transducer (LVDT); **(c)** load cell; and **(d)** electric motor.

where TS = tensile strength, BS = breaking strength, and A = cross sectional area.

Histopathology

Two rats in each group were examined histologically. All specimens were fixed in 10% neutral buffered formalin, dehydrated in graded alcohols, and embedded in paraffin. Sections were stained with hematoxylin and eosin, and additional sections were stained with Ver Hoeff's elastic stain. Histologic evaluation of wound healing was based on visual, subjective examination of new collagen fibers and fibroblast cell population. New collagen deposition was identified by its staining characteristics when viewed after hematoxylin and eosin. New collagen under these conditions stains less intensely than old collagen and does not form the large bundles seen in the original undamaged tissue.

Statistical Analysis

The experiment was performed in a split-plot design with days serving as the main-plot factor and incision type (scalpel, diode, Nd:YAG) as the sub-plot factor. Breaking strengths (group 1) and tensile strengths (groups 2 and 3) served as the dependent variables. Rat body weight was included in the analysis as a covariate to determine if differences in body weights affected the relationships the factors of interest (days and incision type) had on the dependent variables (breaking and tensile strengths).

RESULTS

The average body weight of rats in groups 1, 2, and 3 at the time of testing were 473 gm, 481 gm, and 500 gm, respectively. Rat body weight had no effect as a covariate for either breaking strength (P = 0.5618) or tensile strength (P = 0.6172) and was therefore removed from the model.

On all occasions, stress-strain curves generated for spring distraction calibration tests had an identical slope.

Four of the day 7 laser incisions (two diode incisions and two Nd:YAG incisions) and four of the day 14 laser incisions (one diode incision and three Nd:YAG incisions) were not healed. These incisions were given a zero value for breaking strength and tensile strength, and were included in the statistical analysis calculations.

For both of the dependent variables, there was no evidence of interaction between day and incision type (P = 0.1157 and 0.3295 for breaking and tensile strengths, respectively). Therefore, all conclusions made about incision type should therefore be consistent for all days studied. There was no significant difference in the breaking strengths (P = 0.3941) or the tensile strengths (P = 0.3295) of incisions made with the diode laser and Nd:YAG laser. Breaking strength (group 1) and tensile strength (groups 2 and 3) of the scalpel blade wounds were significantly greater than those of the laser wounds (P-value < 0.001 for all tests).

Histopathology findings were limited to a subjective, blind analysis, due to the small number of rats used.

Day 7 Incisions

The diode laser incisions had slightly less inflammation than the Nd:YAG laser incisions, but

there was little or no collagen production associated with either of the laser incisions. The diode laser specimens had thermal necrosis extending 200 microns from the cut edge, while the Nd:YAG specimens exhibited a 100 micron thermal necrosis zone bordering the margins of the incision. Scalpel incisions had little inflammation, greater numbers of fibroblasts, and small areas of new collagen deposition. The reason for the difference in the rate of initialization of the wound healing response in the laser incisions is the collateral thermal damage associated with laser cutting.

Day 14 Incisions

At this interval, the degree of inflammation, fibroblast population, and new collagen production was similar between the diode and the Nd:YAG lasers. At this point, the wound healing response to the laser incisions had begun but was decreased when compared to the incisions made by scalpel. The scalpel incisions had less inflammation and moderately greater fibroblast populations and collagen formation than seen in the wounds created by either laser. Both of these observations can be attributed to the lack of thermal injury that allowed the normal tissue response to begin immediately, rather than being offset from the normal time frame by necrosis.

Day 21 Incisions

In this group, laser incisions were associated with only mild inflammation, and scalpel incisions had essentially no evidence of inflammation. The scalpel and laser incisions were similar with regard to fibroblast populations and amounts of new collagen deposition. All specimens had reached closure and appeared very similar.

Alternate sections were stained with Ver Hoeff's elastic stain. This stain did not reveal any differences between the incisions made with the scalpel and those made with either laser. There were no increased amounts of elastic fibers in the wound bed of any of these specimens.

DISCUSSION

The photothermal ablation and vaporization capabilities of the Nd:YAG laser are clinically employed in a variety of surgical procedures. Given its near infrared wavelength, wide range of power settings, and fiber optic delivery systems, the Nd:YAG laser is considered quite versatile. However, most models tend to be limited in portability by their large size, high power requirement (generally 3 phase), and water cooling systems. The diode laser, which also has a near infrared wavelength and fiber optic delivery systems, previously had a power output on the order of milliwatts. Notable for its compact size and portability, this semiconductor laser is now available with power outputs of up to 25 W and greater.

In a recent study, a comparison was made between the Nd:YAG and a prototype high power diode laser based on a subjective assessment of cutting ability, hemostasis, and degree of thermal necrosis of various tissue samples [23]. Based on an assessment of these parameters, it was suggested that the laser-tissue interactions were similar. Tissue healing of Nd:YAG and diode laser incisions may be comparable, though no objective data has been provided to support this.

This study provides objective strength measurement data and a subjective assessment of the tissue response of skin incisions made with a high power diode laser and the Nd:YAG laser.

Strength testing and histologic evaluation of rat skin wounds are well described and rats are frequently used as an animal model for human wound healing studies [7,25,26]. Skin wound healing in rats may be affected by age, body weight, estrus cycle, room temperature, nutrition, activity, and hair growth cycle [27–29]. The animals in this study were males of the same age and similar body weight that were all fed the same ration and housed under the same conditions. Statistical analysis using body weight as a covariate established that body weight had no effect on breaking strength or tensile strength.

The accuracy of in vitro tensile strength measurement of excised, devitalized tissue may be limited by cytochemical and mechanical deterioration resulting from ischemia, thermal change, storage media, physical disruption, and age [29–34]. Though in vivo testing would most likely eliminate these potential variables, it requires special instrumentation, presents difficulties in determination of wound cross sectional area, and must be justifiable for humane reasons. The tensiometer and wound healing model used in this study were designed in an effort to eliminate variables introduced with in vitro testing but allow for measurement of wound cross sectional area. For humane reasons, all animals were euthanatized immediately prior to wound distraction.

Results were the same for breaking strength and tensile strength, thus establishing that the

incisional cross sectional area of incisions among rats was the same.

The schedule for tensile strength testing and histologic evaluation was selected with reference to the established time sequence for the development of tensile strength in normal rat skin incised with a scalpel blade [27]. Collagen is responsible for tensile strength. For our purposes, an increase in wound strength due to collagen deposition within a 3-week period was considered sufficient to allow for incisional strength analysis.

Four of the day 7 laser incisions (two diode and two Nd:YAG) and four of the day 14 incisions (one diode and three Nd:YAG) were not healed. Given the effort taken to standardize or eliminate most of the known variables affecting wound healing, the delay in tissue healing is attributed to the degree of necrosis at the margins. The laser incisions showed virtually no collagen formation when compared to the control scalpel incision, and at day 14 the laser incisions had a decreased collagen production compared to the scalpel incisions. The initiation of collagen production was delayed by coagulation necrosis and had not caught up with the events occurring in the control scalpel incisions. During the interval from day 14 to day 21, the production of collagen in the control scalpel incisions slowed and stopped due to wound closure; the laser incisions had reached their peak wound healing activity during this time, and by 21 days they had also reached the required endpoint of wound closure and, as a result, both the laser and scalpel incisions had equal amounts of collagen. The necrosis caused by laser incisions was not severe enough to interfere with the study objective of evaluating the strength of healed incisions. It would, however, preclude clinical use of these lasers for cutaneous incisions in rats.

This study shows no statistically significant difference in the incisional wound strengths of the Nd:YAG and diode laser incisions for each of the three time durations of healing (7, 14, and 21 days). The statistically significant greater wound strength of the scalpel blade (control) incisions for each of the time intervals was not unexpected, especially considering the energy required to penetrate the full thickness of rat skin. The healing process that occurs subsequent to photocoagulation of tissue with the Nd:YAG laser is described as typical of any thermal injury [35]. Generally, the inflammatory cell infiltrate is minimal. The sterile necrotic zone resulting from the absorption of thermal energy prevents exogenous stimulation of inflammation. Endogenous stimulus for an inflammatory response is suppressed due to the local heat denaturation of cellular proteins. Also, the Nd:YAG has been reported to specifically suppress collagen production in both fibroblast cultures and human skin in vivo [36,37]. The mechanism responsible for this inhibition has yet to be determined.

CONCLUSION

Based on the tensiometric wound strength analysis, subjective grading of fibroblast population, and appearance of collagen deposition, it appears that the high power diode laser (805 nm) creates a similar tissue response compared with the Nd:YAG laser. This preliminary information supports further investigation of the high power diode laser for procedures in which the Nd:YAG is utilized.

REFERENCES

1. Nishioka NS. Applications of lasers in gastroenterology. Lasers Surg Med 1995; 16:205–214.
2. Flesicher D. Endoscopic laser therapy for gastrointestinal neoplasms. Otolaryngol Clin North Am 1984; 64:947–953.
3. Rutgeerts P, Van Gompel F, Geboes K, Vantrappen G, Brouckaert L, Coremans G. Long term results of treatment of vascular malformations of the gastrointestinal tract by Neodymium-YAG laser photocoagulation. Gut 1985; 26:586–593.
4. Gostout CJ, Ahlquis DA, Radford CM, Viggiano TR, Bowyer BA, Balm RK. Endoscopic laser therapy for watermelon stomach. Gastroenterology 1989; 96:1462–1465.
5. Viggiano TR. Endoscopic Nd:YAG laser coagulation of bleeding from radiation proctopathy. Gastrointest Endosc 1993; 39:586–593.
6. McDougall JC, Cortese DA. Neodymium-YAG laser therapy of malignant airway obstruction. Mayo Clin Proc 1983; 58:35–39.
7. Shapshay SM, Simpson GT. Lasers in bronchology. Otolaryngol Clin North Am 1983; 16:879–886.
8. Toty A, Personne C, Colchen A, Vourch G. Bronchoscopic management of tracheal lesions using the Nd:YAG laser. Thorax 1981; 36:175–178.
9. Dumon JF, Reboud E, Garbe L, Aucomte F, Meric B. Treatment of tracheobronchial lesions by laser photoresection. Chest 1982; 81:278–284.
10. Bemis JF Jr, Vergos K, Rebeiz EE, Shapshay SM. Endoscopic laser therapy for obstructing tracheobronchial lesions. Am Otol Rhinol Laryngol 1991; 100:413–419.
11. Shapshay SM, Oliver P. Treatment of hereditary hemorrhagic telangiectasia by Nd-YAG laser photocoagulation. Laryngoscope 1984; 94:1554–1556.
12. Rebeiz E, April MM, Bohigian RK, Shapsay SM. Nd-YAG laser treatment of venous malformations of the head and neck: an update. Otolaryngol Head Neck Surg 1991; 105: 655–661.
13. April MM, Rebeiz EE, Friedman EM, Healy GB, Shapsay

SM. Laser therapy for lymphatic malformations of the upper aerodigestive tract: An evolving experience. Arch Otolaryngol Head Neck Surg 1992; 118:205–208.
14. Bhatta KM. Lasers in urology. Lasers Surg Med 1995; 16:312–330.
15. Hoffstetter A. Laser application for destroying ureteral tumors. Lasers Surg Med 1984; 3:152.
16. Smith AD. Percutaneous laser use in the upper tract. In: Smith JA, ed. "Lasers in Urologic Surgery." Chicago: Year Book Medical, 1989; pp 92–100.
17. Ooekler RTC, Beck HX, Frank F. Surgery of the sellar region with the Nd:YAG laser. Fortschr Med 1984; 9:218–220.
18. Fasano VA. Observations on the use of three laser sources in sequence (CO_2-argon-Nd:YAG) in neurosurgery. Lasers Surg Med 1983; 2:199–203.
19. Fasano VA, Urcivoli R, Ponzio M. Photocoagulation of cerebral arteriovenous malformations and arterial aneurysms with the neodymium:yttrium-aluminum-garnet or argon laser: preliminary results in twelve patients. Neurosurgery 1982; 11:754–760.
20. Van Loveren HR, Weil SM, Tew JM Jr. Complete excision of thalamic arteriovenous malformations with neodymium:YAG laser. In: Sawaya R, Tew JM Jr, eds. "Laser Applications in Neurosurgery." Philadelphia: Hanley and Belfus, 1987, pp 447–457.
21 Fasano VA. The treatment of vascular malformation of the brain with laser source. Lasers Surg Med 1981; 11: 609–616.
22. Watson G. Use of a semi-conductor diode laser in urology. SPIE Proc 1994; 2129:121–123.
23. Wyman A, Duffy S, Sweetland HM, Sharp F, Rogers K. Preliminary evaluation of a new high power diode laser. Lasers Surg Med 1992; 12:506–509.
24. Liles JH, Flecknell PA. The effects of buprenorphine, nalbuphine and butorphanol alone or following halothane anaesthesia on food and water consumption and locomotor movement in rats. Lab Anim 1992; 26:180–189.
25. Cohen IK, Mast BA. Models of wound healing. J Trauma 1990; 30:S149–S155.
26. Disa JJ, Vossoughi J, Goldberg NH. A comparison of obsidian and surgical steel scalpel wound healing in rats. Plast Reconstr Surg 1993; 92:884–887.
27. Mast BA. The skin. In: Cohen KI, Diegelmann RF, Lindblad WJ, (eds.) "Wound Healing, Biochemical and Clinical Aspects." Philadelphia: W.B. Saunders, 1992, pp 344–355.
28. Randall P, Dushoff IM. Skin cycles and other physiologic variables of rodent skin: The effect of the skin cycle on skin homograft survival in the mouse. Plast Reconstr Surg 1958; 21:24–41.
29. Levenson SM, Geever EF, Crowley LV, Oates JF, Berard CW, Rosen H. The healing of rat skin wounds. Ann Surg 1965; 161:293–308.
30. Calnan J, Fry HJH, Saad N. Wound healing and wound hormones: a study of tensile strength in rats. Br J Surg 1964; 51:448–456.
31. Marangoni RD, Glaser AA, Must JS, Brody GS, Beckwith TG, Walker GR, White WL. Effect of storage and handling techniques on skin tissue properties. Ann N Y Acad Sci 1966; 136:439–454.
32. Thompson LW, Zook EG, Hugo NE. A tensiometer to measure wound tensile strength in situ. J Surg Res 1969; 9:543–546.
33. Al-Sadi HI, Gourley IM. Simplified method for studying mechanical properties of healing linear skin wounds in the dog. Am J Vet Res 1977; 38:903–906.
34. Van Winkle W Jr. The tensile strength of wounds and factors that influence it. Surg Gynecol Obstet 1969; 129: 819–842.
35. Brackett KA. Tissue interactions of Nd:YAG lasers. In: Joffe SN, Oguro Y, (eds.) "Advances in Nd:YAG Laser Surgery." New York: Springer-Verlag, 1987, pp 336–343.
36. Abergel RP, Meeker CA, Dwyer RM, Lesavoy MA, Uitto J. Non-thermal effects of Nd:YAG laser on biological functions of human skin fibroblasts in culture. Lasers Surg Med 1984; 3:279–284.
37. Abergel RP, Meeker CA, Dwyer RM, Lask G, Kelly AP, Uitto J. Laser treatment of keloids: A clinical trial and in vitro study with the Nd:YAG laser. Lasers Surg Med 1984; 4:291–295.